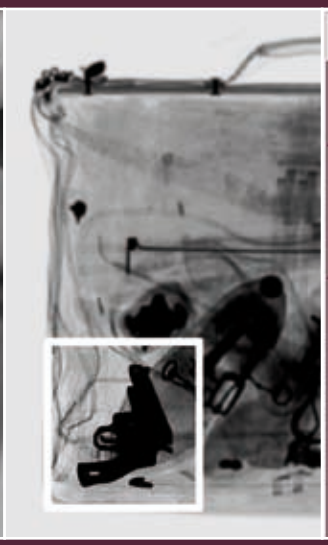
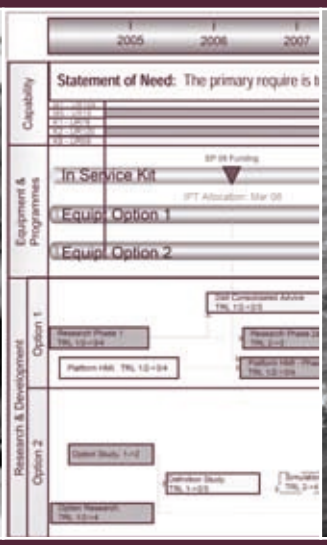
Maximising Defence Capability Through R&D

A review of defence research and development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Foreword

By Lord Drayson, Minister of State for Defence Equipment and Support

Lord Drayson

This review represents a rigorous and comprehensive assessment of the outcomes of MOD's R&D activities. It needs to be seen in the broader context of the major reforms the Government has already made or has set in train in defence acquisition. These include improved partnering with industry through our 2005 Defence Industrial Strategy (DIS) and the formation of the Defence Equipment and Support organisation earlier this year as part of our ongoing Defence Acquisition Change Programme (DACP). These reforms are all designed to further the Government's goals of greater efficiency, innovation, agility and speed in our defence equipment acquisition processes and to foster a spirit of "Team Defence".

Last year, we published the findings of a pioneering evidence-based peer review of the alignment, quality and exploitation of MOD's research[1]. We decided to build on the success of this work by extending the review process - which included the use of external peer review to ensure objectivity - to MOD's much larger research and development (R&D) expenditure. Our purpose was to ensure that our £2.6BN per annum investment in R&D is truly meeting the requirements of the Equipment Programme and ultimately helping to provide our Armed Forces with the cutting edge technology they need and deserve to fulfil their mission.

The review evidence shows that, at project level, our R&D investment is efficient and leads to outcomes that are mostly effective and in some areas, world class, such as the British Experimental Rotor Programme IV (BERP IV) described in this report. The review has also highlighted areas where we need to continue to make improvements, for example in the overall strategic direction and management of our R&D investment, so that we can realise the true value of R&D outcomes. We have already taken a number of steps to achieve improvements in this respect through our DACP, such as the reform of MOD's research budget into 3 research channels, one of which directly supports technology development, and the production of a Research and Development Handbook which will improve the links between DIS sector strategies and the commissioning and exploitation of R&D. This report identifies the further changes we need to make to maximise the benefits of our R&D activities, in particular by managing R&D as a single, coherent entity, under the strategic direction of the new MOD R&D Board, itself another DACP initiative. These changes will be vigorously pursued within the broader DACP processes we already have in hand.

1 "Maximising Benefit from Defence Research" published in October 2006.

Introduction

By Professor Sir Roy Anderson, Chief Scientific Adviser and General Sir Kevin O'Donoghue, Chief of Defence Materiel

'…the UK's battle winning military capability remains heavily dependent on the development, exploitation and insertion of world-class technology'[2]

The Defence Industrial Strategy[3] identified the changes required across the entire Defence acquisition community, including industry, to ensure our Armed Forces continue to receive the equipment they need to respond to the challenges of the 21st Century. The ensuing Defence Acquisition Change Programme[4] has focused on the structure, organisation and process changes required within the Ministry of Defence to deliver better Through Life Capability Management. The formation in April 2007 of the Defence Equipment and Support organisation to replace the Defence Procurement Agency and the Defence Logistics Organisation is the clearest manifestation of the changes we are making.

This work has necessarily been process-led. Of equal importance is the need to assess the quality and effectiveness of the *outcomes* of MOD's processes. The Ministry of Defence spends some £2.6BN annually on research and development (R&D) activities. In April 2006 the Department published the internal report[5] of a pioneering review of the alignment, quality and exploitation of the £500M Defence research programme which forms part of that total. The Defence Management Board decided to extend this successful review (known as the "Capability and Alignment Study"), to cover MOD's entire R&D investment. Our aim was to identify where and how efficiently resources are being utilised, and to what effect. Like the Capability and Alignment Study, this comprehensive evaluation of our R&D performance included the use of external assessors to ensure it was objective and robust.

We also established a Managerial Board to direct and oversee the Review Team's work. The Board included several senior industrialists and academics whose collective experience and expertise made an invaluable contribution to the review, for which we are particularly grateful.

The UK has a good track record in delivering highly capable, battle-winning equipment to its Armed Forces within available resources[6]. The capability of our equipment depends in turn on the output of our R&D investment. The R&D Review Team has found that the Department's R&D activities are mostly working well; indeed, it has identified outstanding examples of world class work. That said, the team has substantiated the judgement of the "Enabling Acquisition Change" report that in some areas we are simply not doing as well as we should. The team's report identifies a number of things we can and should do better. Securing the necessary improvements will be challenging, especially in culture and behaviours. The Department's new R&D Board – itself another Defence Acquisition Change Programme initiative – will lead the Department's response to those challenges and make implementation of the Review Team's recommendations one of its key early priorities.

2 "Defence Industrial Strategy" Cm6697 December 2005 p38.

3 "Defence Industrial Strategy" Cm6697 December 2005.

4 The Department's programme to implement the recommendations of the report "Enabling Acquisition Change" published in June 2006.

5 "Maximising Benefit from Defence Research" published October 2006.

Executive Summary

1. This review was commissioned to provide a detailed and independently verified assessment of MOD's current £2.6BN per annum expenditure on Research and Development (R&D) related activities, to ensure that resources are being used in the most effective way. It addressed seven key questions as to how R&D is defined, the efficiency and effectiveness of expenditure, the quality of the product and how well it is exploited, recorded and communicated. The review drew on independent external experts to ensure objectivity.

2. The Review Team found that MOD's R&D is not presently considered or managed as a coherent whole; as a consequence there is no unifying vision or clear strategic direction. R&D is managed in stovepipes, with little emphasis on through life issues or re-use of cross-cutting technology. Development is not an end in itself and is not therefore managed as a programme and there are no metrics to assess its performance as an entity. The team therefore had to address the seven questions in its Terms of Reference at individual project level, where it judged overall that MOD's R&D activities are mostly working well in outcome terms, but much more could be done in terms of good management, assessment of impact and Intellectual Property Rights generation.

3. The purpose of MOD's R&D investment is to create knowledge and evidence for policy and decision-making and to sustain cost-effective equipment acquisition and through life support. However, the team found that perceptions of the role and purpose of R&D vary considerably across MOD and industry. While a common definition of R&D is widely used throughout the Department, interpretations of that definition differed, and the team found a lack of clarity over work classed as R&D.

4. The team reviewed a sample of projects amounting to around £1BN in value, including 26 major items of R&D across the 16 largest R&D spending Integrated Project Teams. Overall efficiency within the projects reviewed was good but this varied across different R&D activities. The team found little evidence of duplication in the projects in its sample, despite the lack of strategic direction and any systematic mechanisms to identify and avoid such duplication.

5. The team judged that most R&D contracts have clearly defined milestones, that delivery is mostly effective, and that the technical quality of the vast majority of R&D activities meets MOD's needs. It noted, however, that the value and utility of R&D outputs are rarely measured in their own right, in part because payment milestones are not always linked to development achievements.

6. The review found processes in place that should facilitate the successful exploitation of R&D and most of the projects sampled had pulled through into the programme. Nevertheless, a number of R&D projects in the sample had not been exploited successfully, nor were they likely to be in the future, through lack of joint planning and co-ordination between R&D sponsors. The team also found that there is no central repository for the capture of knowledge and findings from MOD-funded R&D and no formal mechanism, requirement or incentive to disseminate R&D findings to wider communities for possible use on other projects. It found evidence of increasing use of technology road mapping. However, the overall consistency, quality and use of road mapping and technology planning were variable, especially for immature and cross-cutting technologies.

7. The majority of MOD's R&D expenditure results in Intellectual Property owned by industry to which the Department enjoys user rights. This is not catalogued centrally and the team found little evidence of localised Intellectual Property management. Only the relatively small proportion of MOD-owned Intellectual Property generated through its R&D investment is catalogued and administered with the aim of external exploitation. As a result, the Department does not sufficiently value past R&D or realise its full potential benefit.

8. The team conducted extensive wider consultations in order both to ascertain external views on MOD's R&D processes and performance and to identify current good practice in the management, conduct and review of R&D. Based on the outcome of these consultations, the evidence collected through its project reviews and its analysis of that evidence, the team drew key conclusions and made a number of recommendations regarding the future management and conduct of MOD's R&D activities.

9. The report's key recommendation is that MOD should in future manage both research and development as a whole. There would also be advantage in managing R&D with increased focus on technology sectors or groupings, rather than at the level of individual projects. The Review Team concluded that this can be achieved across existing organisations and budgetary structures but recommended that the MOD R&D Board drives this change and should start by setting some stretching goals for improved performance of R&D as a whole. The Board should also provide clear strategic direction for the coherent performance of R&D based on outcomes relevant to Defence. These outcomes will be enabled through the alignment of commercial, procurement and industrial policies and strategies. In providing strategic direction for MOD's R&D, the R&D Board also needs to examine carefully the balance of R&D investment by Defence Industrial Strategy sector in relation to current and future capability needs in theatres of operation.

10. The team's other recommendations are designed to help spread current good practice across the full range of MOD's R&D activities by improving communication, data capture, and, as a consequence, exploitation. They include proposals for the regular review of R&D performance and assessment of benefits - in particular through improved use of Post Project Evaluation - and instilling greater pace and flexibility in the contracting and management of R&D.

11. The team proposed, finally, that the Department's Defence Acquisition Change Programme should take account of the outcome of this review and assess any consequential changes that will be required in the Department's R&D culture and behaviours.

Chapter One

Introduction

1.1 MOD currently reports some £2.6BN per annum expenditure on Research and Development (R&D) related activities. The Chief Scientific Adviser and the then Chief of Defence Procurement[7] jointly commissioned a detailed and independently verified review of this investment to ensure that resources are being used in the most effective way. The full Terms of Reference are at Annex A. Key questions for the study to address included:

a) The clarity of R&D definitions and where resources are being spent.

b) The efficiency of R&D expenditure and whether there is any duplication or any repetition of work.

c) The effectiveness of R&D expenditure: whether outputs meet requirements and whether R&D proposals are properly assessed.

d) The quality of R&D outputs, based on independent peer review.

e) R&D exploitation, including arrangements for intellectual property.

f) Whether R&D data is captured effectively.

g) The communication of R&D knowledge to other interested parties.

The Review Team was to draw on the methodology devised by the recent Capability and Alignment Study into MOD's research programme[8] .

Review Team

1.2 The Review Team was jointly led by two MOD Senior Civil Servants supported by other MOD and external personnel. A Managerial Board under the joint chairmanship of MOD's Chief Scientific Adviser and the then Chief of Defence Procurement was established to oversee the review. The Board comprised key MOD stakeholders and several external members, including senior industrialists and academics to ensure impartiality and objectivity (the full composition is at Annex B).

Review Methodology

1.3 The Review Team undertook extensive consultations with other Government Departments, industry and other Governments to scope the review, devise its methodology, and to establish best practice in the conduct and review of R&D. A full list of those consulted is at Annex C.

7 Following the merger of the Defence Procurement Agency and the Defence Logistics Organisation on 2 April 2007, this post has been amalgamated with that of the Chief of Defence Logistics under a new post, Chief of Defence Materiel.

8 "Maximising Benefit from Defence Research" published October 2006

Chapter Two

Aims, Benefits and Definition of MOD's R&D

Key findings

- The purpose of MOD's R&D investment is to create knowledge and evidence for policy and decision-making and to sustain cost-effective equipment acquisition and through life support.
- However, perceptions of the role and purpose of R&D vary considerably across IPTs and industry.
- The Review Team was able to reconcile the £2.54BN R&D investment reported by Departmental financial management systems in 2005/06 with separate itemised returns from individual business units to within £15 million (0.6%) of the total; however, this required considerable time and effort due to the lack of a coherent management information system and database for R&D.
- While a common definition of R&D is widely used throughout the Department, interpretations of that definition varied, and the Review Team found a lack of clarity over work classed as R&D. Current processes hinder IPTs' visibility of what has been undertaken by the contractor in respect of payments reported as R&D; for example, in some instances the team found that reported R&D expenditure was an estimate based on an agreed percentage of the overall equipment contract (i.e. it could not be broken down into itemised R&D work).
- The current Resource Account Codes do not allow sufficient discrimination between types of R&D, the phase of the equipment project and non-technology development such as provision of legal or commercial advice. They also provide little understanding of the benefits of MOD's R&D investment.

Why MOD Invests in R&D

2.1 The UK's battle-winning military capability depends heavily on its investment in R&D. MOD's R&D activities include the development of technology, systems, and architectures as well as design, test and evaluation. R&D creates robust knowledge and evidence in support of policy and decision-making through the provision of operational, acquisition and capability analysis. It generates enhanced performance and new capabilities. It also enables cost and risk reductions and interoperability with close allies. Most R&D supports the Concept, Assessment and Demonstration phases of the equipment acquisition cycle (CADMID[9]), and enables through-life technology insertion. It provides our Armed Forces with a vital military edge over commercial off the shelf systems, makes MOD an "intelligent customer", and helps underpin the competitiveness and innovation of UK defence industry. A recent study has shown that absolute spend on R&D can be related to defence equipment advantage (in terms of years[10]) . The challenge for defence is to relate the benefits of R&D investment to cost of ownership and value for money within the acquisition cycle.

9 Concept, Assessment, Demonstration, Manufacture, In Service, Disposal.

10 Middleton, A, Bowns, S, Hartley, K and Reid, J (2006). *"The effects of Defence R&D on Military Equipment Quality"* Defence and Peace Economics 17 117-139.

R&D Definitions

2.2 To establish where R&D resources are being spent, the Review Team took the UK's Statement of Standard Accounting Practice 13 (SSAP 13) definition of R&D, as adapted for the public sector by the Government Financial Reporting Manual 2006-7 (see Box). SSAP 13 is based on the 'Frascati Manual' prepared by the Organisation of Economic Co-operation and Development and is used by MOD in the definition of "Intangible Fixed Assets".

2.3 The team found that, in practice, an element of judgement is required in deciding whether project work should be classed as R&D. Indeed, Defence Statistics Bulletin No 6 acknowledges the "difficulties of categorising expenditure on large defence projects" and notes that "Subjective assessments are required to separate development from pre-production expenditure." A previous National Audit Office review of the classification of Defence R&D[11] observed that the extent to which the various phases of MOD's equipment programme fall within the Frascati definition of experimental development is not clear and concluded that all phases probably include some elements of Frascati and non-Frascati work.

Extract From The United Kingdom's Statement of Standard Accounting Practice 13 (SSAP 13)[12]

"(a) Pure (or basic) research: Experimental or theoretical work undertaken primarily to acquire new scientific or technical knowledge for its own sake rather than directed towards any specific aim or application;

(b) Applied research: Original or critical investigation undertaken in order to gain new scientific or technical knowledge and directed towards a specific practical aim or objective;

(c) Development: Use of scientific or technical knowledge in order to produce new or substantially improved materials, devices, products or services, to install new processes or systems prior to the commencement of commercial production or commercial applications, or to improve substantially those already produced or installed."

2.4 Under the SSAP 13 definitions, MOD essentially carries out 'Applied Research' where scientific and technical knowledge is generated and advanced in a defence context and 'Development' when exploiting such knowledge to create new or improved materials, devices, architectures and systems. MOD does not undertake 'Pure Research'.

2.5 The review focused on the £2.54BN R&D expenditure reported by MOD's financial management systems[13] in 2005/06. This included a centrally managed £500M activity by the Science Innovation and Technology Top Level Budget (henceforth referred to as "the research budget") that underpins the Department's technical capability and decision making. This is commonly referred to as the 'research programme' but under SSAP 13 definitions includes both research and development. Integrated Project Teams (IPTs) in the Defence Equipment and Support organisation commissioned a further £2.0BN of R&D work as part of the equipment acquisition and support process. The Review Team sought itemised financial returns from all IPTs reporting expenditure against R&D Resource Account Codes that year.

2.6 While MOD's financial reporting systems facilitate the identification of contracts and contract elements recorded as R&D, the fidelity of the breakdown by line item varied across IPT returns. However, the Review Team was able to reconcile the itemised returns to within

11 NAO Report '*Classification of Defence Research and Development Expenditure*' HC105 12 December 1991.

12 Issued by the Institute of Chartered Accountants (revised January 1998).

13 MOD Annual Report and Accounts 2005/6 and Defence Analytical Services Agency and Central Finance and Planning Group statistics.

£15M (0.6%) of the £2.54BN total, albeit this took considerable time and effort due to the lack of a coherent management information system and database for R&D. In subsequent interviews with IPTs and industry, the team tried to identify the accounting definitions they had used, so it could understand IPTs' perceptions of the role and purpose of R&D and how R&D suppliers had allocated funds.

2.7 The Review Team used IPT returns to categorise MOD's £2.54BN R&D expenditure by Defence Industrial Strategy[14] sector and position in the CADMID cycle as shown in Figures 1 and 2 below. The team observed that the distribution of spend can be distorted by major projects as they pass through critical phases of the CADMID cycle, such as the Joint Combat Aircraft (JCA) in 2005/6. Figures 1 and 2 also therefore show the distribution of expenditure with JCA excluded.

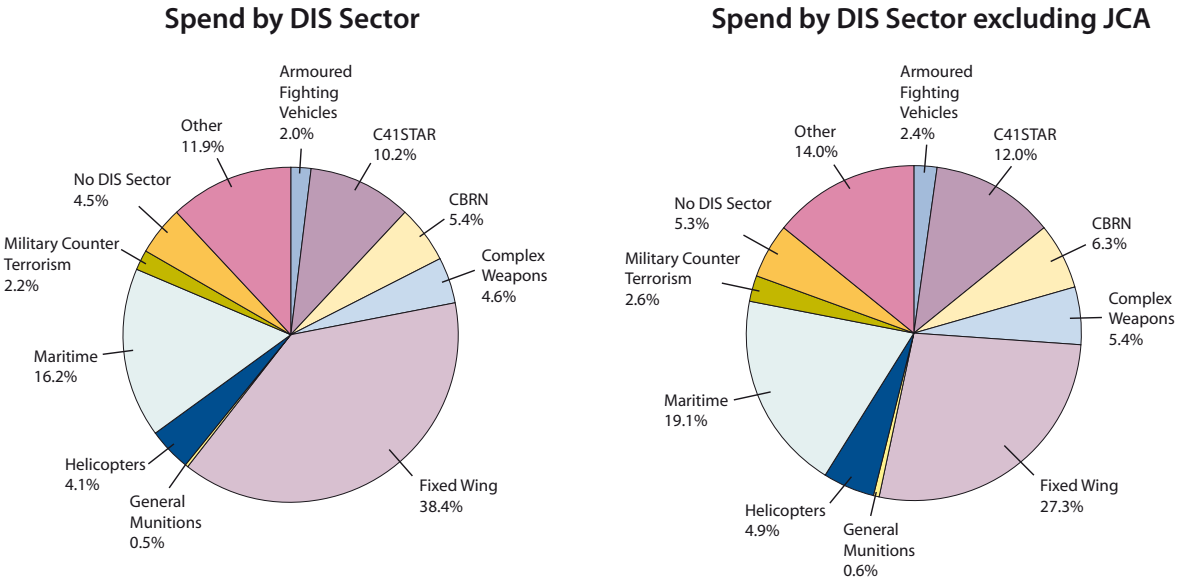

Figure 1: R&D spend by DIS sector, with and without Joint Combat Aircraft (JCA)

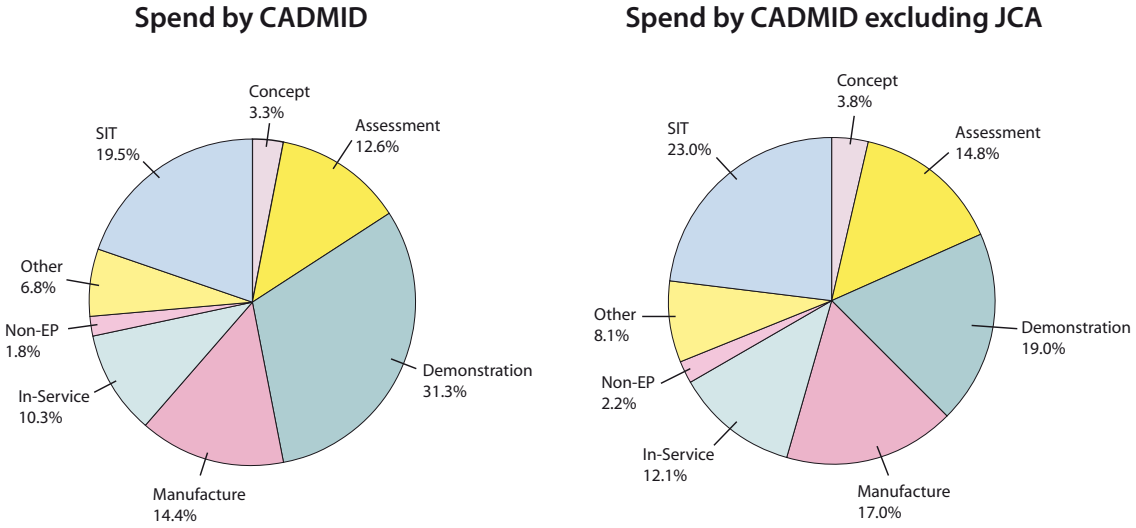

Figure 2: R&D spend across Science Innovation and Technology Top Level Budget (SIT) and the CADMID cycle, with and without Joint Combat Aircraft (JCA)

14 "Defence Industrial Strategy" Cm6697 December 2005.

2.8 The distribution of R&D investment across the Defence Industrial Strategy sectors mirrors the overall equipment spends in these sectors. Even excluding Joint Combat Aircraft, Figure 1 shows that, reflecting the technical complexity and safety constraints, the fixed wing sector received the largest share of R&D investment in 2005/6. Figure 2 shows that across the CADMID cycle, the demonstration phase attracted the largest expenditure (31%) that year. R&D expenditure in the manufacture phase mostly comprised non-recurring costs in the manufacture of prototypes and first of class platforms.

2.9 Although the central research programme funded by the research budget accounts for only 20% of total R&D expenditure, the programme covers all MOD's research needs[15]. While it is not directly tied to specific IPT projects, over half of the programme supports equipment capability development.

2.10 Scrutiny of IPT financial returns revealed that definitions of R&D used by finance staff were generally consistent with Departmental guidance, assuming a broad interpretation of SSAP 13. However, there were differing interpretations of what constitutes R&D and some areas lacked clarity:

a. Expenditure reported as R&D often included items such as business processes, legal and commercial advice and document archiving, which are necessary for equipment acquisition but are not technical. IPTs acknowledged they had used a broad interpretation of SSAP13 for this type of work in the absence of a more suitable account code. Such work should not, in the team's view, be classed as R&D, even though it contributes to the intangible value of the equipment.

b. R&D expenditure may be obscured in the accounts where it is funded via a multinational intermediary authority (eg. A400M and Joint Combat Aircraft) or a Private Finance Initiative contract (eg. Skynet 5). In such cases, the contract or Memorandum of Understanding does not always allow the IPT detailed visibility of R&D expenditure.

2.11 The Capability and Alignment Study in 2006 also highlighted definitional issues in the research programme. These concerned the existence of contracts for Defence Science and Technology Laboratory (Dstl) support to help the Directors of Equipment Capability to identify capability gaps and research requirements and for 'Knowledge Integration' activity within Dstl. The Study Team did not question the need for such projects, but queried whether they could legitimately be categorised as "research" in the traditional sense since they did not generate new knowledge or technology. These issues are currently being addressed by the Research Acquisition Organisation and the Defence Acquisition Change Programme process.

2.12 The R&D Review Team found that whilst R&D payments were usually linked to project deliverables, current processes did not always allow IPTs visibility of work actually conducted by the contractor in respect of such payments. This was particularly the case for large 'Design For Manufacture' payments in post-Main Gate projects. In two of the biggest contracts, the sum reported in 2005/06 against R&D was an agreed percentage of total contract expenditure deemed to be R&D when the contract was let and was not necessarily a bottom up reflection of actual R&D work completed that year. Taking ASTUTE as an example, the team had to contact the Prime Contractor to gain an understanding of what R&D had been carried out in respect of a £78M payment in 2005/06. Achieving a breakdown of R&D activities was made more difficult as the sum reported was just such a percentage of work estimated to be R&D rather than a separately identifiable work package.

2.13 Although the team found the use of accounting definitions was generally consistent, perceptions of what constitutes R&D and why it is needed at different stages within the CADMID cycle varied considerably. Some IPT staff considered that they did not undertake R&D, despite reporting substantial expenditure against R&D account codes. In such cases, they often perceived R&D as research only. The team also noted that some of the Operational Analysis funded by the research budget in support of policy or Equipment Programme-

15 The research programme was reviewed as part of the Capability & Alignment Study in 2005/6 (published under the title 'Maximising Benefit from Defence Research' in April 2006).

funded decision support might not fall strictly within the SSAP 13 definitions of R&D. For example, Operational Analysis using established models to develop high level policy or verify force structure and equipment procurement numbers should not, strictly, be classified as R&D; but development of models or Operational Analysis to define and validate new equipment concepts can legitimately be classified in this way.

2.14 The Review Team found that MOD's current Resource Account Codes afford little visibility of where and how R&D resources are being spent because they do not align with a taxonomy of R&D spend and are not therefore useful for analysis. For example, R&D expenditure with QinetiQ or Dstl is currently required to be booked against a single code for each organisation with no demarcation of the R&D activity or the project stage. R&D expenditure with other suppliers, at best, differentiates accruals pre- and post-Main Gate. The team also found that MOD's accounting process for reporting IPT payments to prime contractors did not align well with industry's own methods for accounting for R&D spend. This possibly contributed to the lack of clarity over specific R&D expenditure by some of the larger IPTs. Significantly, current Resource Account Codes also afford little understanding of the benefit that the Department accrues from R&D – whether knowledge creation, technical services or acquisition of hardware.

2.15 MOD's new Defence R&D Board will require accurate data on where R&D funds are being invested. Such data collection would be improved by developing a clearer MOD working definition of R&D, building on existing definitions such as those set by the Organisation of Economic Co-operation and Development but tailored to meet MOD's specific needs. The Department's accounting codes also need to distinguish more accurately and capture the costs of both R&D and non-R&D work or non-technology development in support of acquisition. Contracts and stage payment invoices should be required to break down expenditure against the revised codes. Steps should also be taken to capture any R&D investment within Private Finance Initiatives. A communications effort would help to establish common usage of terminology across the entire MOD R&D community through improved guidance, training and processes.

AFFORDABLE THERMAL IMAGING

High performance Thermal Imagery (TI) is a key enabler for operations conducted under the cover of darkness or in poor visibility. However, Thermal Imaging technology is relatively expensive for widespread use in the land environment.

In 2004, a novel Thermal Imaging technology demonstrator programme was initiated using a systems engineering approach. Its aim was to improve essentially off-the-shelf technologies to deliver extended performance and military advantage but at an affordable cost. This led to the Quantum Well Infrared Photo detector (QWIP) camera, which set new standards in off-the-shelf technology performance but at 50% of the price of the previous generation cameras and in a configuration suitable for mounting into legacy platforms. The demonstrator was jointly funded by industry and MOD and sets best practice in closer working relationships between the two.

The development was judged to be very successful after extensive trials in 2006/7 at the UK Armoured Trials Development Unit and with operational units deployed in Iraq. The Commanding Officer of the operational unit reported that the camera was a genuine force multiplier for reconnaissance operations and was user friendly.

Chapter Three

The Seven Questions: What We Found

Key findings

- MOD's R&D is not presently considered or managed as a coherent whole. As a consequence there is no unifying vision or clear strategic direction against which the Review Team could assess R&D investment. Instead, its analysis focused on how well R&D has performed at the project level.
- Overall efficiency within the projects reviewed was good but there was a variation across different R&D activities.
- There was little evidence of unintentional duplication in the sampled projects despite the lack of systematic mechanisms to identify and avoid such duplication.
- IPTs rely upon internal and external knowledge and experience (e.g. within Dstl, Directors of Equipment Capability and other subject matter experts) to make efficient use of crosscutting and background R&D, particularly that funded by the research budget. However, clearer guidance is required to ensure such checks take place. Greater collaboration and awareness is needed both within and across traditional sector boundaries to improve coherence, especially in crosscutting technologies.
- Tangible R&D output (i.e. hardware, software and documentation) is reviewed as part of formal contractual acceptance but broader R&D effectiveness (i.e. the value and utility of the R&D output in its own right) is rarely measured. Most R&D contracts have clearly defined milestones and delivery is mostly effective. However, payment milestones are not consistently linked to tangible development achievements, making it impossible to measure R&D effectiveness.
- The utility or value of R&D is not always assessed, and Post Project Evaluation is rarely used to draw lessons for the future contracting of R&D.
- The technical quality of the vast majority of MOD's R&D activities meets IPT needs.
- Processes are in place to allow the successful exploitation of R&D and the majority of the projects sampled had pulled through into the programme. However, a number of projects in the sample had not been exploited successfully, nor are they likely to be in the future, through lack of joint planning and co-ordination between R&D sponsors.
- While road mapping is increasingly used, the overall consistency and quality is variable, particularly for immature and crosscutting technologies.
- MOD-owned Intellectual Property is catalogued and administered with the aim of external exploitation. However, industry-owned Intellectual Property resulting from the majority of MOD's R&D spending is not catalogued centrally and the team found little evidence of Intellectual Property Rights management at an IPT level or by individual Research Directors in the Research Acquisition Organisation. As a result, the Department does not sufficiently value past R&D or realise its full potential benefit.
- No central repository exists for the capture of knowledge and findings of MOD funded R&D, there is no coherent R&D database and no formal mechanism, requirement or incentive to disseminate R&D findings to wider communities for possible use on other projects.

Process & scope

3.1 MOD's R&D is not presently considered or managed as a coherent whole; as a consequence there is no unifying vision or clear strategic direction. The Review Team therefore had to address the seven questions in its Terms of Reference at the individual project level rather than at a more strategic level (the broader implications of this significant issue are addressed in Chapter 4).

3.2 To assess R&D performance, the team selected a representative sample of contracts and activities in 16 of the largest R&D spending IPTs, excluding Joint Combat Aircraft[16], but accounting for £920M of R&D in 2005/6, and a random sample totalling over £50M of other R&D activities.

3.3 The team used external experts to provide an independent and objective assessment of these samples, primarily in respect of quality and effectiveness. Team members, with systems experts from Sula Systems and BMT, assessed 26 major items of R&D across the 16 largest spending IPTs. The team divided the £50M random sample - comprising over 100 R&D contracts - into two categories: R&D concerned with technology development and R&D concerned with other support to IPTs' work, including trials, consultancy and assessment. This work was reviewed by team members with subject experts from the Defence Scientific Advisory Council. Over 80% of activities in the sample were valued at less than £1M[17].

The new General Purpose Respirator, developed from research by Dstl Porton Down

3.4 Where possible, the Review Team concentrated on work actually carried out in 2005/6, in order to base the review on the most recent audited R&D expenditure. Assessment was either through a review of published reports and project documentation or by face-to-face presentation to the reviewer by industry or IPTs. Review of the major R&D items was carried out by interview. Projects were scored individually against the questions in the Terms of Reference.

3.5 For its assessment of *efficiency*, the team relied on external reviewers' awareness of comparable work to identify duplication (either actual or potential) or detect where new work had failed to build on existing foundations. The sampling approach did not find many clear examples of unintended duplication. The team therefore looked for evidence of processes and behaviours that would ensure co-ordination, coherence and avoidance of duplication over time and across sectors and organisations.

3.6 The Review Team assessed R&D *effectiveness* by considering how well projects and activities were meeting their stated objectives. Where possible, Statements of Work were used to identify these objectives, although it was difficult sometimes to obtain documentation, particularly when projects had since moved between IPTs. The team found that most R&D after Main Gate concerns design for manufacture, acceptance and design validation prior to production. While this was often accounted as a line item in the main contract, individual Statements of Work or objectives did not always exist and R&D effectiveness was hard to assess in isolation from the overall project.

3.7 To assess R&D *quality*, the team drew on methods developed by the Capability & Alignment Study but recognised that metrics used for assessment of research are not appropriate for all R&D - particularly that concerned with design, development and manufacture of equipment.

3.8 *Exploitation* of R&D is difficult to assess, given the timescales often involved between initiation of R&D and eventual use in fielded equipment. Where no clear exploitation path

16 Almost all Joint Combat Aircraft R&D is carried out in the US, which did not allow assessment in the time available for the review.

17 Contracts funded by the research budget were not specifically included, as these had already been assessed during the Capability & Alignment Study – "Maximising Benefit from Defence Research" Oct 2006.

existed, the team looked for an audit trail, such as technology road maps or R&D plans, Intellectual Property management and pull through both into and out of post-Main Gate programmes. The team also consulted experts in the Defence Equipment and Support organisation to gain a greater understanding of Intellectual Property management in MOD.

3.9 To assess R&D *communication* and *data capture*, the team sought evidence of best practice and use of 'Learning from Experience' and Post Project Evaluation exercises. It also considered usage of a central data repository such as Dstl Knowledge Services and participation in colloquia, communities of interest or industry days.

Efficiency

3.10 Overall *efficiency* of MOD's R&D activity is good; there is little duplication and good re-use of R&D where appropriate. However, this varies between IPTs. Figure 3 shows scores from both samples as a measure of the efficiency of IPTs' R&D activities.

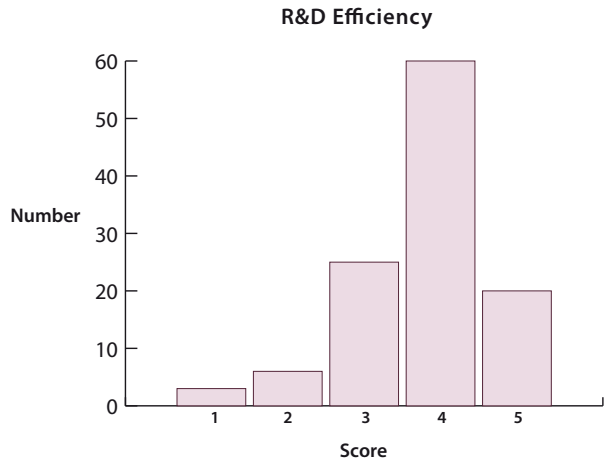

Figure 3: Scores for efficiency of R&D activities

3.11 The Review Team found no MOD-wide mechanisms in place to identify and prevent unintentional duplication across the Department's R&D activities. However, in some areas existing local processes, networks and structures helped to ensure the efficiency of R&D and the avoidance of duplication, e.g.

- The Future Carrier IPT conducted a comprehensive technology survey at the outset of the project to establish a portfolio of technologies ready for incorporation in the design;
- the Future Rapid Effect System Capacity and Stowage Technology Demonstrator Programme made use of Dstl's experience in developing similar requirements for the Infantry Training and Development Unit;
- the structure of the Future Rotor-Craft IPT as a cluster of projects encouraged collaboration between rotary wing projects to reduce duplication and combine efforts where most needed.

HMS ASTUTE (Image courtesy BAE Systems ©)

3.12 In other cases, avoidance of duplication was the result of a highly specialised field with a small community of experts. For example, ASTUTE R&D work is directed within prime contracts

and there is little scope for duplication within the Under Water Effects capability area despite the prime contractor's lack of visibility and co-ordination of the central Under Water Effects research and technology programme. However, relying on a small community of expertise does not prevent duplication with comparable R&D work at sub-system level within other capability areas or environments.

3.13 There were instances of deliberate duplication in the form of competitive demonstration e.g. in Future Rapid Effects System IPT, Land Environment Air Picture Provision and in the UK Co-operative Engagement Capability project where early Assessment phase work is being repeated to update assessments of technologies that may have matured during a 5-year delay.

3.14 Responsibility for avoiding duplication of R&D within IPTs is neither clearly defined nor specifically resourced. IPTs have little exposure to R&D work in other sectors or other organisations, while high staff-turnover risks a lack of awareness of background R&D sponsored previously within the IPT. As a result, IPTs tend to rely on their long-serving members, the Directors of Equipment Capability, Dstl and subject matter experts in external bodies such as QinetiQ for awareness of crosscutting and background R&D. The Review Team judged that this is insufficient, especially given staff turnover, and a mandatory process may be required to improve efficiency. Despite such networks across IPTs, traditional sector boundaries remain e.g. land, sea and air and can hinder the transfer of relevant knowledge between sectors.

3.15 The team observed that horizon scanning for new technology opportunities had greatest value when it was an integral part of the overall R&D activity, rather than a separate initiative. However, it generally found that there is insufficient scanning for new technology opportunities by IPTs commissioning R&D and Technology Demonstrator Programmes. The introduction of Director General clusters within the new Defence Equipment and Support organisation should facilitate the elimination of duplication and maximise the exploitation of cross-cutting technology planning. The newly created Science Gateways[18] and the new Technology Development Channel[19] should also facilitate such collaboration.

3.16 Very few IPTs use databases and not all conduct formal searches for background R&D work. The absence of a single repository of R&D knowledge - or at least one that is used consistently by all - also increases the risk that technology surveys will overlook important background work. The team concluded that greater collaboration and awareness is needed both within and across traditional sector boundaries to reduce the risk of duplication and improve coherence, particularly in cross-cutting technologies. Effective technology searches to provide a portfolio of background or related R&D for both IPTs and prospective contractors should be made common practice at the outset of the Concept and Assessment phases of projects. These should involve suitably experienced subject matter experts and should contribute to technology road maps and technology insertion plans.

3.17 Whilst systems engineering methodologies were employed at the Prime Contractor level, there was less evidence of a similar approach within MOD. Technology work funded by the research budget was not always systematically planned for Equipment Plan exploitation and Equipment Plan R&D activities were not always systematically planned for optimum pull through. Such system breakdown into key sub-systems within MOD's R&D would improve delivery of defence capability by ensuring that the whole system is considered in context. This would improve:

- traceability with previous activities, identification of needs and requirements management;

18 Experienced scientists and engineers helping the Defence Equipment and Support organisation plan appropriate technology for insertion through life to deliver effective capability solutions.

19 The research budget is now divided into 3 new funding "Channels". The other two are "Enabling Research" and "Capability Planning and Management".

- accountability for future lifecycle stages and exploitation routes, including cross cutting opportunities;
- achievement of appropriate system and technology maturity levels;
- management of system integration issues, in particular the relationship with: external systems required to sustain the system in service; collaborative systems required to deliver a military effect; and other systems potentially competing for resources such as bandwidth, electromagnetic spectrum, power, weight etc;
- communication with key stakeholders in working towards a common purpose for acquisition;
- identification of priorities and greatest returns for Defence.

Effectiveness and Quality

3.18 Overall, MOD's R&D is *effective* in meeting requirements, with no perceivable differences due to project size and type of R&D activity.

3.19 Where distinct R&D tasks existed, supported by business cases and formal Statements of Work, the Review Team found clear evidence that individual projects were well managed and rarely failed to meet their contractual objectives, although in some instances - particularly for complex projects - achievement of milestones was delayed. After Main Gate, where R&D expenditure forms part of the capital equipment cost, technical risk is reduced to a minimum and failure of R&D is unlikely.

3.20 Figure 4 shows scores for R&D effectiveness for both large and small projects, based on whether milestones reflected the original requirement clearly and were met, and whether tasks were managed effectively (ie. technical risk was considered and technology maturity assessed and reviewed, e.g. using Technology Readiness Levels).

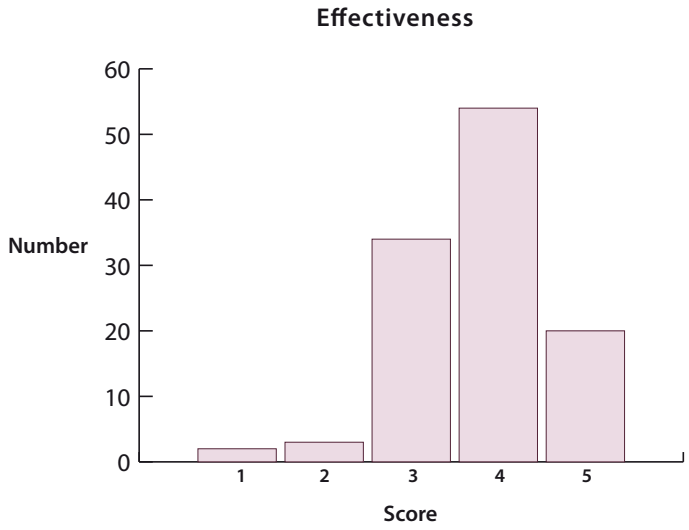

Figure 4: Distribution of scores as a measure of effectiveness across R&D activities

3.21 The team found examples where platform requirements had changed or procurement had stopped, leading to poor use of R&D and therefore poor effectiveness, even though the R&D had met the original contractual requirements (similar examples were found by the Capability and Alignment Study in the research programme). In such cases there was a lack of flexibility in the R&D contracting mechanism to adapt to these changes.

3.22 R&D contracting arrangements are usually focused on generation of hard deliverables and are essentially similar to those used for equipment procurement. Milestones were found to be well-defined and being met for the majority of the projects reviewed, with evidence that incentivised milestones were improving performance. However, the team found that payment milestones, particularly for large projects, were not always related to tangible development achievements; this made it difficult to measure R&D effectiveness. Where the R&D does not result in a tangible deliverable, the contract is based around production of a report. The team

A400M TRANSPORT AIRCRAFT DEVELOPMENT

A400M is being developed to meet the military requirements of 7 European Nations, including the UK's. Since 2005, two non European Nations have also joined. The first aircraft is expected to fly in 2008, with delivery of aircraft to the UK from 2009. Each nation contributes to the non-recurring costs of aircraft development in proportion to its total order. On this basis the UK pays some 10% of these costs. The UK's full financial contribution to the programme (both non-recurring and recurring costs), which is presently in the demonstration phase of its procurement, is some £2.3BN.

The A400M programme aims to harmonise the military requirements of partner nations in order to achieve a single platform configuration but still allow partners a degree of variation on sub-systems e.g. defensive aid suites. The harmonised requirement was matched to available Commercial Off The Shelf technologies, which were integrated to provide a low risk but a highly effective military capability. R&D was undertaken to gain an understanding of the performance and cost envelopes of the various commercial technologies, their development and integration into the air platform and to build a demonstration aircraft.

Examples of innovative technology incorporated include composite materials for the wing and the turboprop powerplant (the largest ever developed in the West). In addition, Airbus Military Systems used new and efficient aircraft manufacturing techniques and developed novel support and sustainability solutions involving rapid turnaround times and use of latest Life Time Monitoring Systems. This project has extended the performance offered by the civil sector in key areas within the constraints of the overall budget. In so doing, the project has helped to develop and sustain the Airbus industrial capability.

observed that while it is easy to assess whether a report has been delivered for the basis of payment, the utility or value of the R&D itself was not always assessed. This contrasts with industry practice, where the team found that a key criterion for R&D investment and indicator of effectiveness is an assessment of "value added". Moreover, lessons from how the R&D was specified and contracted were rarely used to improve contracting of future R&D – an issue previously highlighted in the NAO's "Gold Standard" on contracting[20].

3.23 The overall *quality* of MOD's R&D is mainly good and the most appropriate contractors are being used. However, there is no absolute measure of R&D quality. Generating new scientific knowledge or pushing the boundaries in technology requires a leading edge appreciation of the technical area, together with a sound approach. Design qualification or assessment requires individual equipment expertise, while design for manufacture requires sound engineering experience. For post-Main Gate development projects, the IPTs' focus is on programme deliverables rather than the achievement of best in class technologies. The external reviewers nonetheless found many examples of high quality, best in class R&D.

3.25 Figure 5 shows the review's scores for quality. Where its assessment was based on a review of printed reports and other documentation, the team found wide variations in report quality. In some instances, key pieces of information about particular trials or studies were omitted. The value of such documentation - and ultimately the R&D itself - will be limited without the knowledge held by the contractor and IPT staff.

3.26 The Capability and Alignment Study showed that MOD's entire research programme could be subjected to periodic external peer review - a process now being introduced. This review has demonstrated the feasibility of extending external review across the Department's broader R&D activities.

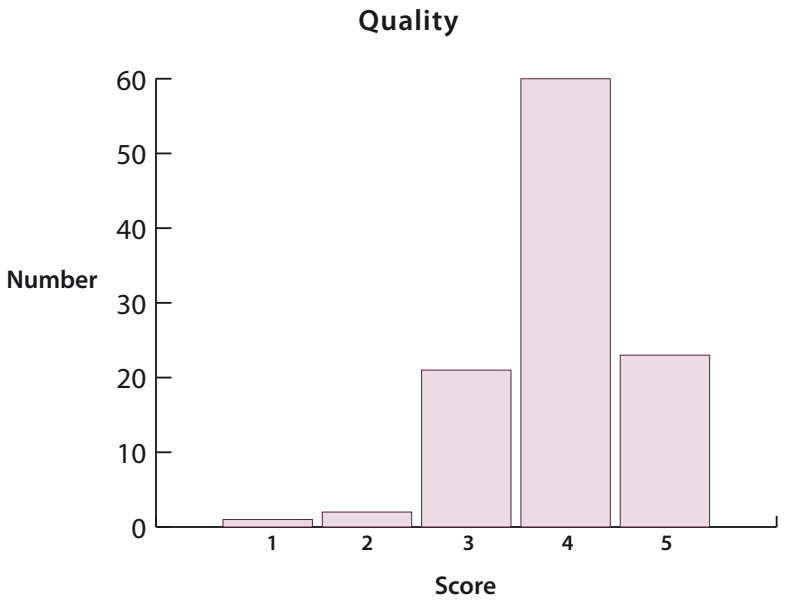

Figure 5: Distribution of scores as a measure of R&D quality

20 "Using the contract to maximise the likelihood of successful project outcomes". HC1047 Session 2005-2006 June 2006.

Exploitation

3.27 The majority of projects sampled had pulled though into the Equipment Programme. However, some projects had not been exploited successfully nor were they likely to be through lack of joint planning and co-ordination between R&D sponsors.

3.28 The Review Team assessed exploitation by how effectively MOD used R&D and the intellectual property generated from it. Depending on the intended outcomes of individual R&D projects, this could range from use in decision-making to pull through into equipment and Front Line use. The team found processes in place to allow successful exploitation of R&D, such as those advocated in the Technology Management Strategy used by the Defence Equipment and Support organisation. However, exploitation depends heavily on the degree of consultation and information sharing across the research, acquisition and supplier communities at all project stages; this varied widely in different project areas.

Generation of Intellectual Property

3.29 Most MOD-funded R&D generates intellectual property owned by the prime contractor but to which MOD secures the necessary user rights to allow exploitation. In some cases, such as Nuclear Chemical & Biological protection, MOD owns the intellectual property.

Management of Intellectual Property and Intellectual Property Rights

3.30 MOD catalogues and administers its own intellectual property and aims to exploit it externally e.g. current work with Ploughshare Innovations Ltd[21] to exploit patents held by Dstl. However, intellectual property owned by industry with MOD user rights is not catalogued centrally. The team found little evidence of intellectual property rights management, with the exception of multinational programmes such as Future Carrier, where rights are declared at key stages such as the start and end of contract phases.

3.31 Determining the correct intellectual property conditions requires some indication of the 'end use' to be established at the start of R&D. However, the team found that intellectual property exploitation is not considered sufficiently early in R&D planning and assumptions made with respect to exploitation are not challenged or updated as the R&D develops.

3.32 When appropriate MOD contractual conditions for intellectual property had been applied, there were examples where these had not been enforced in respect of contract deliverables. The team found reports incorrectly marked "company proprietary" or "company copyright" when they should have been "Crown Copyright". It also found cases where only a 'limited rights' report had been accepted but the contract also required the delivery of a 'full rights' report. Acceptance of R&D deliverables with incorrect markings or ones not meeting contractual conditions can later complicate wider exploitation and means that MOD has not received what it paid for.

Exploitation of Intellectual Property

3.33 The Review Team generally found evidence of processes in place to facilitate R&D exploitation. As the assessment in Figure 6 shows, technology road maps or R&D plans existed across many of the IPTs reviewed. Future Carrier was an example of best practice, where a Whole Ship Technology Insertion Plan was in force during 2005/6[22]. However, the overall consistency, quality and use of road mapping and technology planning was variable. Improving it is a priority for the Defence Equipment and Support organisation in the new cluster construct.

21 Established by Dstl to improve spin out of MOD research.

22 This has now been replaced by the Aircraft Carrier Alliance Technology Management Policy.

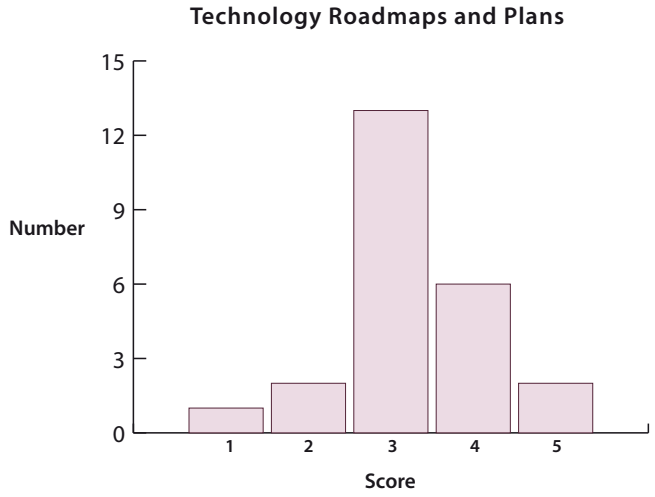

Figure 6: Assessment of Technology Roadmap and R&D plan development within the major R&D spending IPTs

3.34 R&D within the major spending IPTs, especially in the Demonstration phase after Main Gate, is generally focused on specific platform or system issues. Exploitation into these platforms and systems was good. Wider spin-out into other projects was poor, but the Future Rotorcraft cluster showed good practice in its emphasis on exploitation across all rotary wing projects,

3.35 The team found a wider variation in exploitation of smaller R&D activities (less than £1M). A large proportion of this R&D had been successfully exploited or was likely to make an impact in the future. In several cases, however, R&D had not been exploited nor was it likely to be. Some projects had not been sufficiently matured (de-risked) to allow exploitation, sometimes due to a lack of funding. In others, the main programme targeted for pull through did not include exploitation plans for the R&D in question.

3.36 The team also observed that technology road maps for immature and crosscutting technologies were less effective. Such technologies by their nature feed into a number of projects and are often delivered by second or third tier suppliers. Uncertainty as to which candidate technologies are likely to be incorporated in equipment 10-15 years hence makes linkages to specific decision points and milestones in individual technology road maps difficult. More effort is required to develop road maps in these areas.

3.37 Much R&D retains a value long after it has ended, but MOD does not effectively capture this value and re-use the knowledge gained. Fast-moving technology areas, especially those which provide a potential lead for the Armed Forces, have a limited life in which to identify wider exploitation opportunities. Better exploitation planning will help considerably, but further action is necessary to identify the opportunity costs of downstream decisions - or lack of decisions - that result in investment in technical knowledge not being used. The team concluded that the application of systems engineering principles (see para 3.17) to planning and defining R&D will help in this regard.

3.38 These findings are consistent with the Capability and Alignment Study's assessment of research exploitation, which emphasised the importance of exploitation plans, technology road maps, and end user/ stakeholder engagement, but noted that performance in this respect varied widely.

FUTURE AIRCRAFT CARRIER TECHNOLOGY INSERTION PLAN

The Future Aircraft Carrier (CVF) is being developed to play a crucial role in the delivery of the UK's Carrier Strike capability. To fulfil its requirement, CVF needs to install and host a wide range of systems, many of which - including the Joint Combat Aircraft and its supporting infrastructure - are still subject to R&D programmes.

To monitor the development of these systems and to ensure informed and timely decisions on their adoption, CVF has followed a robust technology management process that has been implemented through a technology insertion plan. This forms an integral component of the Through Life Management Plan and sets out a strategy that:

- identifies candidate technologies for meeting the requirement and the means by which they can be acquired;
- defines a common set of terms to ensure consistent and objective technology maturity assessment that is focused on the operational environment;
- incorporates technology maturity assessment as an integral component of the risk and opportunity management process, defining appropriate mitigation plans and fall back options to ensure the right technology is available at the right maturity at the right time; and
- allows informed technology investment decisions to be deferred as late as possible without jeopardizing the overall programme.

CVF has successfully used the technology insertion plan to monitor the development of a wide range of systems including the Highly Mechanised Weapon Handling System, Wireless and Planar Array communication equipment and elements of the power and propulsion solution.

Communication and data capture

3.39 The Review Team found a wide range in the quality and means of communicating R&D outcomes, but overall this was an area of weakness in projects sampled. It attributed this to the absence of a central MOD repository and a formal process for the capture and dissemination of knowledge. The team also found more evidence of information push into the wider community than of organisations actively seeking to pull information from external sources.

3.40 IPTs and industry were frequently unaware of Dstl Knowledge Services, or the help it could provide as a repository of knowledge and information. Even where IPTs knew of its existence, processes to ensure its use were not widely known or understood. Exceptions were the Research Acquisition Organisation and Defence Equipment and Support's Integration Authority which routinely pass material to Dstl for incorporation into Knowledge Services. The team also found that when Dstl is tasked to support a project, it does not routinely catalogue and store all relevant project material, unless this service has been specifically requested and resourced.

3.41 The team found that heavy reliance is placed on experienced personnel for the management of knowledge, e.g. rotorcraft knowledge is retained through staff within the Future Rotorcraft and individual platform IPTs. Individual R&D studies were found to be platform specific, managed by the respective IPTs and not disseminated more widely. However, the team noted that the large body of information generated in the development of ASTUTE would be transferred from its current owner, the Submarine Production IPT, to the Submarine IPT in the next two years. The library will be further reviewed to establish how it can best be integrated into the existing in-service submarine library which is maintained by DML for MOD.

3.42 There is no formal MOD-wide mechanism to disseminate R&D findings to wider communities. However, the team found several examples of communication through stakeholder meetings and quarterly reviews with representatives from industry, IPTs, Research Acquisition Organisation, Director Equipment Capability, and Dstl amongst others. The Research Acquisition Organisation uses several formal mechanisms to disseminate knowledge, including industry/supplier days, theme days, capability working groups, quarterly reviews and Towers of Excellence. Information dissemination also occurs through informal networks and ad hoc meetings, but this relies heavily on individuals and whether they stayed in the same field.

3.43 Learning from Experience and Post Project Evaluation events are standard practice in many IPTs. For example, the A400M IPT participated in a Learning from Experience exercise with the Hercules IPT and Sensors, Avionics and Navigational Systems IPT for its Defensive Aids Suite. Some projects keep related databases, such as the Nimrod Learning from Experience database. However, industry considered MOD should undertake more systematic Post Project Evaluation. The team observed that Learning from Experience and Post Project Evaluation, if systematically employed across all R&D, would allow MOD to capture vital underlying technical knowledge and understanding on risk reduction within acquisition projects.

3.44 The lack of a central MOD knowledge repository and formal mechanisms for communication severely limits the likelihood of wider exploitation as IPTs are unable easily to search for relevant R&D from other projects. Even where it is known that other IPTs have performed relevant R&D, obtaining the reports can be difficult.

3.45 The Review Team found very little evidence of effective Data Capture from MOD's R&D spend through databases or other means (see Figure 7 for data capture scores). Since there is no distinct R&D programme, there is no coherent R&D database, nor is there a central repository for R&D records and information. Securing access to detailed contract information and schedules of work for the projects selected for review was therefore often difficult and time-consuming. Most contracts were held locally by individual IPTs and were not always available. Similar concerns over data capture in the research programme were identified by

the Capability and Alignment Study, whose report recommended the establishment of a single database[23]. The team noted that Future Rapid Effect System IPT had a contract with its Systems House to provide an R&D database at the end of the initial Assessment Phase.

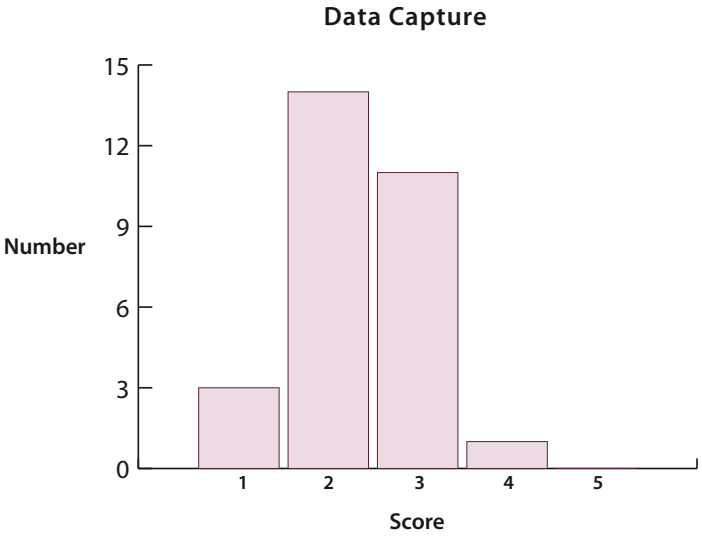

Figure 7: Assessment of Data Capture within the major R&D spending IPTs (scores of 1 and 2 represent unsatisfactory practice).

3.46 The team concluded that a digital database supported by local research domain and IPT cluster R&D plans is required to spread and exploit knowledge within MOD. This will help avoid duplication and repetition of work, and help provide a strategic overview of R&D investment for the MOD R&D Board. Routine breakdowns of R&D spend by individual line item would allow a database system to be used for the review of quality, effectiveness and efficiency. Such a database should draw on the data fields identified by this review to capture key R&D information. However, the management overhead in populating and maintaining such a database would need to be identified and resourced and incentives provided to ensure accurate data capture.

23 This will be met by the Science and Technology Research Information Management System (STRIMS) database, which will capture finance and programme information for research funded by the Science Innovation and Technology Top Level Budget.

BERP IV - DEVELOPING A NEW LIFT FOR ROTORCRAFT

© Burkhard Domke

Battlefield Helicopters make a key contribution to the agility and flexibility of the UK's Armed Forces. The British Experimental Rotor Programme (BERP) IV was aimed at maturing a new generation of composite main rotor blades for UK helicopters to improve hover and flight performance, reduce rotor-system life-cycle costs, vibration and helicopter signature, and improve supportability. The programme also offered more efficient production and manufacturing methods over current blades.

BERP IV rotor blades on a RAF Merlin Mk3 helicopter were demonstrated to meet improved aircraft performance and anticipated new operational capability goals. This has led to a commitment by the Secretary of State for Defence for the procurement of BERP IV rotor blades for operational deployment by the end of 2007.

So successful is BERP IV performance that it has proved a significant factor in the choice for the next US Presidential Helicopter, an EH101 based VH-71, which will feature a derived version of the new rotor system. New rotor systems, based on BERP IV technology, are also being considered for other UK helicopters, including Future Lynx, Sea King and, in the longer term, Apache.

BERP IV is recognised as a key area in the Defence Industrial Strategy and one in which the UK has a world lead. A US Department of Defense and NASA review in 2003 concluded that the UK's capability focused approach in rotor design, manufacturing and flight testing was ahead of the US; in particular the review noted the benefits accrued from long-term partnerships between Government, industry and the technology supplier base.

Chapter Four

Observations on Good R&D Practice

4.1 The Review Team conducted extensive wider consultations in both the civil and Defence sectors to identify current good practice in the conduct and review of R&D (see Annex C).

R&D Definitions and Organisation

4.2 Like MOD, UK industry uses the Frascati definitions of R&D since these determine the granting of tax credits. Industry R&D tends to be either managed centrally, or managed within operating divisions (equivalent to MOD's IPTs), depending on company size. Large companies favour a hybrid approach, leaving typically 10-20 % of the R&D budget centrally controlled. Some of the highest performing companies also allow their most talented researchers 'free time' to think about topics outside the company portfolio (commonly referred to by Japanese industry as 'under the table' projects); this fosters a culture that maintains and attracts good people. Any invention the company cannot exploit is often licensed to third parties.

4.3 Companies concentrate effort on strategic decisions and direction at a point where they have the greatest ability to change and influence the project outcome, even though R&D expenditure is relatively small at early project stages. The Review Team was advised that most high performing companies employ a 'gated' process for R&D and exercise strong strategic leadership. Timely delivery of a project or product is often more crucial for success than keeping to cost because late entry into a market can have damaging effects on sales. Similarly, early compromises in R&D can have later unforeseen knock on effects in reliability and consequential costs in rectification. For example, US civil sector companies generally place greater emphasis on delivering a product on time, if necessary going over budget on development to achieve this, rather than delaying a project to control costs.

4.4 The team found that companies plan and manage their R&D over both short and long term time horizons (e.g. 3-10 and 10-20 years). Research formulation involves a variety of methods, but usually includes some form of peer review process, whether internal or external. There is a significant emphasis on systems engineering techniques (see para 3.17).

Efficiency

4.5 Companies mostly avoid duplication by peer review and or corporate/board level funding decisions for R&D and a reliance on a central R&D laboratory to maintain overall awareness of company R&D. This contrasts with MOD's current project centric approach.

Quality and Effectiveness

4.6 Measures of R&D effectiveness and quality include achievement of project milestones, timely completion for a product line and competitiveness/ state of the art. Internal and external peer reviewers are used to make such judgements.

Exploitation

4.7 The Review Team found a variety of approaches to enhancing the prospects of R&D exploitation. These include the use of road mapping (from both technology and product perspectives, particularly in Japanese industry), communication through workshops and technology reviews, and embedding of R&D engineers in product teams. There is also an emphasis on re-use of R&D where possible.

URGENT OPERATIONAL REQUIREMENTS – R&D MODEL

Procurement through Urgent Operational Requirements (UORs) offers apparent advantages in terms of the pace of acquisition and ultimate deployment compared to procurement through traditional technology development. Indeed, a recent National Audit Office report recommended that lessons from the procurement of capabilities through UORs should be applied more widely[24]. The Review Team therefore considered whether any aspects of the UOR process could be used to expedite conventional R&D contracting and technology exploitation.

Key attributes of the UOR approach are:

- **a focus on enhancing current military capability with proven technology which is either available for deployment off-the-shelf or requires minimal adaptation and poses low levels of technological risk and uncertainty;**
- **rapid deployment of a generally short term solution to an immediate operational need rather than one aimed at achieving the most cost-effective long term sustainability and integrated logistics support;**
- **a process driven strongly by a pull from the Front Line (where the capability gap lies), IPTs and the Equipment Capability Customer, with the R&D community acting in a largely supporting - but essential - advisory role.**

The evolutionary and flexible nature of the UOR process often involves concurrent requirements generation and business case approval. Routine R&D can and does benefit from the agile UOR approach, which has been introduced in the procurement of Network Enabled Capability. Strong Front Line awareness of potential and evolving solutions significantly helps rapid pull-through of technology within the UOR process. Conventional R&D could therefore benefit from greater involvement of end users in assessing technologies. For example, there is potential merit in using the 'trials development units' to assess prototype and demonstrator programmes, where resources permit, (e.g. the Army Technology Development Unit (ATDU)).

A key difference between regular procurement and UORs is that the latter are procured for very specific roles, while by definition, regular procurement has to consider a wide set of scenarios and possible uses for the equipment. This results in a more complex and potentially longer development and procurement path. Routine procurement and associated R&D often involve large and more technically complex capability, with in-service life typically of several decades, which requires a more complex balance of time, cost and performance. A good example is the fixed wing environment. By contrast, many UORs tend to require less development work and so are less expensive.

Not all the benefits of the UOR approach can therefore be transferred to regular acquisition of R&D, in particular where there are significant technical risks and unknowns in long-term supportability or logistics burden. That said the effectiveness of the UOR process offers lessons that can be usefully transferred into mainstream procurement of R&D and technology.and potentially longer procurement path. Routine procurement and associated R&D often involve large and more technically complex capability, with in-service life typically of several decades, which requires a more complex balance of time, cost and performance. A good example is the fixed wing environment. By contrast, many UORs tend to require less development work and so are less expensive.

24 National Audit Office Report "The Rapid Procurement of Capability to Support Operations" HC1161 Session 2003-2004 19 November 2004.

Not all the benefits of the UOR approach can therefore be transferred to regular acquisition of R&D, in particular where there are significant technical risks and unknowns in long-term supportability or logistics burden. That said the effectiveness of the UOR process offers lessons that can be usefully transferred into mainstream procurement of R&D and technology.

Chapter Five

Strategic Implications, Conclusions and Recommendations

5.1 The evidence from this review and from the Capability and Alignment Study, shows that, in **outcome** terms, MOD's Research and Development activities are mostly working well. There is good use of basic tools such as Technology and Systems Readiness Levels, and increasing use of technology road mapping. However, improvements are required in data capture and communication, which in turn affect exploitation performance.

5.2 At the **strategic** level, there is presently no unity of purpose for MOD's R&D and key decisions are taken on an individual project rather than a broader basis. There is therefore scope for improvement in the way MOD places, manages and reviews R&D.

Leadership of MOD's R&D

5.3 The review has shown that there is no single, agreed statement on the purpose of MOD's R&D because the Department's £2.6BN annual R&D expenditure is not managed as a coherent overall programme. It is managed in stovepipes, each optimised to local delivery across the Science Innovation and Technology area and IPTs within the Defence Equipment and Support organisation. There is little emphasis on through life issues or re-use of cross-cutting technology in the management of Defence R&D, partly due to the lack of coherence across the parts. R&D is not an end in itself and is not therefore managed as a programme and there are no metrics to assess its performance as an entity.

5.4 A central recommendation from the review is that MOD should in future consider and manage R&D as a whole, with increased focus on technology domain programmes, rather than individual projects. This significant change of emphasis would require the raising of expectations and the introduction of revised structures, tools and incentives, building on the Enabling Acquisition Change report and the ensuing Defence Acquisition Change Programme.

5.5 To drive this change, the MOD R&D Board will develop a unified purpose and management approach for Defence R&D, which might be:

a. To enable Through Life Capability Management by providing new scientific and technical opportunities and responding in an agile way to emerging requirements (push and pull).

b. To provide MOD with strategic and long term scientific and technical knowledge.

It will set stretching goals for improved performance of R&D as a whole, pitched over a 3-5 year period in recognition of the time required to deliver major changes in behaviours and culture. The Board will also assume the following key roles:

a. To ensure that the purpose of MOD-funded R&D is commonly understood and implemented.

b. To provide strategic direction for the coherent performance of R&D based on outcomes relevant to Defence. These should include:

i. The creation of sound strategic intentions through mature plans of technology sectors or groupings for the near and longer term, reviewed regularly at senior level up to and including the R&D Board.

ii. The alignment of R&D with Defence Strategic Guidance through coherence with the

Defence Industrial Strategy, the Defence Technology Strategy and military needs.

iii. The creation of conditions necessary to maximise the outcomes from MOD investment in R&D, including alignment of commercial, procurement and industrial policies and strategies.

iv. The delivery of R&D through successful aggregate performance of research projects against key business case criteria and subsequent exploitation.

v. The agility of R&D, measured by the degree to which the programme is adjusted by stopping work that is no longer needed or is poorly performing, in order to provide the headroom to address new priorities.

This significant change will require leadership at all levels and coherent behaviours across the MOD R&D community.

5.6 The R&D Board will need to make informed balance of investment decisions on MOD's R&D expenditure. This may require changes in objectives, structures and training. A consistent approach to technology management across the R&D community will be required, based on the key principles of understanding technology opportunities and managing technology risks in projects; jointly planning technology resources and outcomes; appropriately trained staff with the required skills; and working together with industry.

Management of MOD's R&D

5.7 The review has demonstrated that the management of individual R&D projects is usually sound, but that there is little focus on ways to share knowledge between areas or to exploit opportunities in different areas. The present organisation of R&D and current skill sets amongst practitioners reinforce stovepiped approaches and do not drive the behaviours needed.

5.8 There is scope to increase the flexibility and the pace of R&D. The Review Team found few examples of R&D being stopped (the Capability and Alignment Study made a similar observation). The creation and use of a common Management Information System, based on a database recording R&D activities, is an essential enabler for better management.

5.9 The Review Team found little top-down emphasis on the need to exploit successful technology development. Exploitation tends to be inconsistent and linear, due to several factors. Firstly, R&D planning needs to be more coherent, with a mix of push and customer pull approaches, and R&D business cases need to include a sharper focus on technology road maps and exploitation. Secondly, there would be advantage in using systems engineering techniques to enable the identification of technology drivers and cross-cutting opportunities between domains. Thirdly, past R&D needs to be better valued and its broader use in other projects monitored in future. Fourthly, MOD needs to develop an Intellectual Property Register or database to facilitate better communication of R&D outcomes. Finally, the Department should review current intellectual property rights and commercial approaches to establish whether companies can be encouraged to make use of R&D outcomes in other areas to support MOD's needs. There is also a requirement for wider consideration of longer term commercial procurement perspectives before the start of R&D contracts.

Full Recommendations

5.10 This review set a precedent by addressing R&D as a whole. The Review Team compiled a substantial body of evidence to answer the 7 questions posed in its Terms of Reference. A series of recommendations arise from the review, which address different aspects of project control, further to improve MOD's current R&D performance. These are brigaded in Table 1 below against 4 key levels, broadly as set out in the NAO report on the "Gold Standard" for project control[25].

25 "Driving the Successful Delivery of Major Defence Projects: Effective Project Control is a Key Factor in Successful Projects". HC 30, Session 2005-2006 20 May 2005.

Implementation

5.11 Implementation of the review recommendations will be carried forward under the umbrella of the Defence Acquisition Change Programme process.

Table 1 Full Recommendations of the R&D Review by NAO "Gold Standard" Levels of Successful Project Control

No.	Recommendation	Chapter
	STRATEGIC DIRECTION	
(i)	MOD should manage R&D as a whole with greater coherence across strategies and policies and a clear and defined focus to create unity of purpose.	5.4/5.5
(ii)	MOD should manage R&D with increased focus on planning across technology sectors or groupings, rather than individual projects.	5.4
(iii)	There should be a systematic routine review of R&D expenditure drawing on the questions and methodology adopted for this review as appropriate. The R&D Board should assess the results annually; this should include Learning From Experience and Post Project Evaluation data.	
(iv)	All R&D activities should have clear and dynamic exploitation plans, including technology road maps, which illustrate risk reduction and technology management. These should be reviewed, scrutinised and updated on a regular basis.	3.33
(v)	There should be a management information system to enable strategic decision making. This should be based on a digital database of all MOD-funded R&D, open to use by all areas involved in R&D.	3.46
(vi)	An intellectual property register, cataloguing the various technologies and the associated MOD rights, needs to be produced to engender a more pro-active approach to managing and exploiting such property for the benefit of MOD and the UK.	3.30
(vii)	The current MOD Resource Account Codes should be reviewed to distinguish and capture more accurately the costs of R&D and non-R&D work for acquisition so that the information in any future R&D database (see para 3.46) is precise.	2.15
	MEASURING PROGRESS AND MAKING DECISIONS FOCUSED ON SUCCESSFUL PROJECT DELIVERY	
(viii)	The R&D Board should set some stretching goals for improved performance of R&D as a whole, particularly data capture, exploitation and communication; it should also consider introduction of Systems Engineering techniques to improve planning and delivery of R&D. These goals should cover a 3-5 year period to recognise the time required to deliver significant changes in behaviours. The R&D Board should measure progress against these goals on a regular basis.	5.5

(ix)	R&D business cases should also be required to specify current and target Technology Readiness Levels to enable assessment and communication of success.	3.22
(x)	Metrics should be developed to require Research Directors and IPTs to assess the technology de-risking achieved by R&D in addition to the formal acceptance criteria used for contracted deliverables.	3.22
(xi)	Correct intellectual property conditions should be applied to R&D contracts (e.g. Crown Copyright for reports, where appropriate, and relevant full user rights for technology); this should prevent restrictions on subsequent use and exploitation. Contracted deliverables should be assessed to ensure these conditions are properly met.	3.32
(xii)	The external peer review process now being implemented for the research programme should be extended to other elements of MOD's R&D, as agreed by the R&D Board.	3.26
	CREATING CLEAR STRUCTURES AND BOUNDARIES	
(xiii)	A clearer working MOD definition of R&D should be established, building on existing definitions and tailored to meet MOD's needs as appropriate.	2.15
(xiv)	The R&D Board should consider by December 2007 whether any wider changes are needed - e.g. to R&D objectives, structures or training or to Departmental strategies and policies - to implement our recommendations.	5.5
	ESTABLISHING AND SUSTAINING THE RIGHT CULTURAL ENVIRONMENT	
(xv)	The R&D Board should develop a statement on the overall value of R&D to Defence needs; this should be regularly updated and communicated widely.	
(xvi)	Staff training, development and objectives should be used to drive a sharp awareness of the need to work across boundaries, to seek opportunities for re-use of technologies, improve coherence and avoid duplication.	3.14-16
(xvii)	The Department should use systems engineering techniques to identify technology drivers and opportunities to promote greater efficiency and effectiveness, and to identify cross-cutting technologies.	3.17
(xviii)	There needs to be greater flexibility in R&D contracting to deal with poor performance or to accommodate changes to requirements, threats and exploitation opportunities. R&D contracts should therefore include annual break clauses.	3.21
(xix)	R&D requirements should be tested by Approving Officers to ensure they meet the overall needs of the equipment system or platform, including Defence Lines of Development other than equipment.	3.22
(xx)	MOD should establish a central MOD-wide knowledge repository for the capture of R&D outputs to facilitate their exploitation and avoid duplication of past work. Dstl Knowledge Services could be used for this purpose and contract conditions changed to require routine data capture with minimal overhead for IPTs.	3.39

(xxi)	A uniform, MOD-wide mechanism should be mandated to disseminate findings of R&D more effectively to all areas involved in commissioning R&D.	3.42
(xxii)	In keeping with the spirit of Defence Industrial Strategy, the R&D Board should consider meeting regularly with industry presence - we suggest twice yearly - to foster closer cooperation with industry.	

Annex A

Terms of Reference

AIM

1. To provide a detailed and independently verified review of research and development spending in MOD to ensure the most effective use of resource into the future.

SCOPE

2. The study will address the £2.6 billion the Department spends on Research and Development. It should build on the work commissioned by CSA on the £500 million Research & Technology programme but include work commissioned by the Integrated Project Teams within Defence Procurement Agency and Defence Logistics Organisation and the specialist Support Groups.

COMPOSITION

3. The R+D Review team will initially comprise:

2 x 1* Senior Civil Servants (1 x Full Time, 1 x Part Time);

3 x Band B (or equivalent);

4 x Band C (Fast stream or equivalent).

REPORTING

4. The R+D Review team will report to both the Chief Scientific Adviser (CSA) and the Chief of Defence Procurement (CDP), through the Science & Technology Director and Technical Director.

MANAGERIAL BOARD

5. A Managerial Board, chaired by CSA, will be formed to oversee the review and provide strategic guidance to the Team.

METHODOLOGY

6. The Study will address the following areas:

i) Are there clear definitions of where R&D resources are being spent?

ii) Efficiency of the R&D spend – is it being duplicated elsewhere, and is it repeating work that has been done previously in the research programme?

iii) Effectiveness of spend – does the R&D deliverable meet the initial requirement? Is there a process for assessing R&D proposals before and after contract?

iv) Quality of R&D output – how does the deliverable rate against technologies? This area should be suitable for independent peer review.

v) Exploitation of the R&D – is there Intellectual Property, is it pulled through into the project and is it properly managed?

vi) Data capture – how effectively is data about the R&D captured? Should there be a

proper database system to capture key information about R&D projects, similar to the Science Innovation and Technology STRIMS database?

vii) Are there arrangements for communicating R&D knowledge and lessons learnt to other interested parties in MOD and, with appropriate safeguards, in industry?

CONSULTATION

7. The R+D Review Team will consult widely with key customers and stakeholders for research and development within the Department and with MOD's major research and equipment suppliers. The Team will seek out best practice in the review of research within Government and UK industry and key Allies/other Governments.

Annex B

Composition of R&D Review Managerial Board

Prof Sir Roy Anderson	Chief Scientific Adviser	Co-Chairman
Sir Peter Spencer	Chief of Defence Procurement	Co-Chairman
Mr Paul Stein	Science & Technology Director	
Lt Gen Andrew Figgures	Deputy Chief of the Defence Staff (Equipment Capability)	
Mr David Gould	Deputy Chief Executive, Defence Procurement Agency	
Mr Tim Flesher	Deputy Chief of Defence Logistics	
Mr Trevor Woolley	Finance Director	

Professor Sir Keith O'Nions FRS FREng	Director General of Science and Innovation, Department for Business Enterprise & Regulatory Reform
Prof Julia King CBE FREng	Vice Chancellor Aston University
Mr Alex Dorrian	Chief Executive Thales UK plc
Mr Richard Parker FREng	Director Research and Technology, Rolls-Royce Group
Dr Graham Spittle	Vice President and Director of the IBM Hursley Laboratory
Prof Terry Lazenby FREng FIChemE	Seamab Consultancy Ltd

In attendance:

R&D Review Team	Secretariat

Annex C

Individuals and Organisations Consulted

Within MOD

CSA
DCDS(EC)
DCE, DPA
S&T Director
DCDL
DGE
DGRP
DTD
PD DAC
DI ST
DCSA
Dstl

Other Organisations

AWE
British National Space Centre
Department of Trade and Industry
Hitachi
Matsushita
Nissan
Office of Science and Innovation
Porton Capital
QinetiQ
Roke Manor Research Ltd
Rolls-Royce plc
SELEX Sensors and Airborne Systems UK
Sharp
Thales
Toshiba

US Office of Technology Transition, Department of Defense
US Office of the Assistant Secretary of the Army
US Office of the Assistant Secretary of the Navy
US Office of Navy Research
US Office of Planning Budget and Analysis, Department of Energy
US National Institute of Allergy and Infectious Diseases, National Institutes of Health

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